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Characterization of Nighttime Light Variability Over the Southeastern United States

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Introduction

- City lights provide indications of human activity during nocturnal hours
- Nighttime satellite imagery offers snapshots of this activity via low-level light detection capabilities
- The degree to which city lights fluctuate over time, however, is not well known
- For the application of detecting power outages, this degree of variability is crucial for assessing reductions to city lights based on statistical trends
- In this study, eight southeastern U.S. cities are analyzed to understand the relationship between emission variability and several population centers
- A preliminary, example case power outage study is also discussed as a transition into future work

Science Application

- Detection of power outages requires a thorough understanding of "normal" nighttime light variability
- With the degree of variability known, any reduction following a severe weather event can be classified by statistical significance
- An example approach is to generate multi-image, pre-event composites which can be compared against post-event, single image arrays to determine percent of normal emissions
- If generated in near real-time (NRT), a power outage detection product like the one mentioned would benefit disaster response efforts by providing a spatial estimate of damage following severe weather

Data

- Observations from the VIIRS Day/Night Band (DNB) can detect nighttime emissions from cities, natural gas flares, lightning and boats
- Through collaboration with Goddard Space Flight Center (GSFC), a 1 km gridded DNB product which isolates city light emissions was acquired
- This product serves as the historical archive of city light emissions and a baseline for monitoring their variability over time
- Nightly data was acquired for: Jan. 19, 2012 – Sept. 10, 2015
- Individual city extents were masked from the DNB data using the 2014 U.S. Census Metropolitan Statistical Area (MSA) shapefile

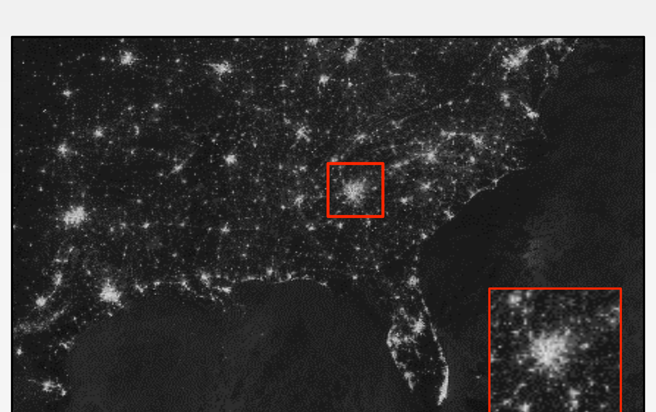

Figure 1: Example DNB image over the southeastern U.S. A subset of Atlanta, GA is also shown for detail at the individual city-scale.

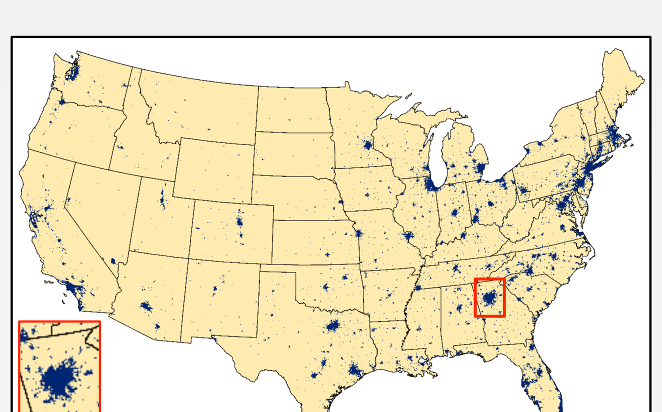

Figure 2: 2014 U.S. Census MSA shapefile over CONUS. A subset of Atlanta, GA is again shown for detail and extent at the individual city-scale .

CONUS Composite Imagery

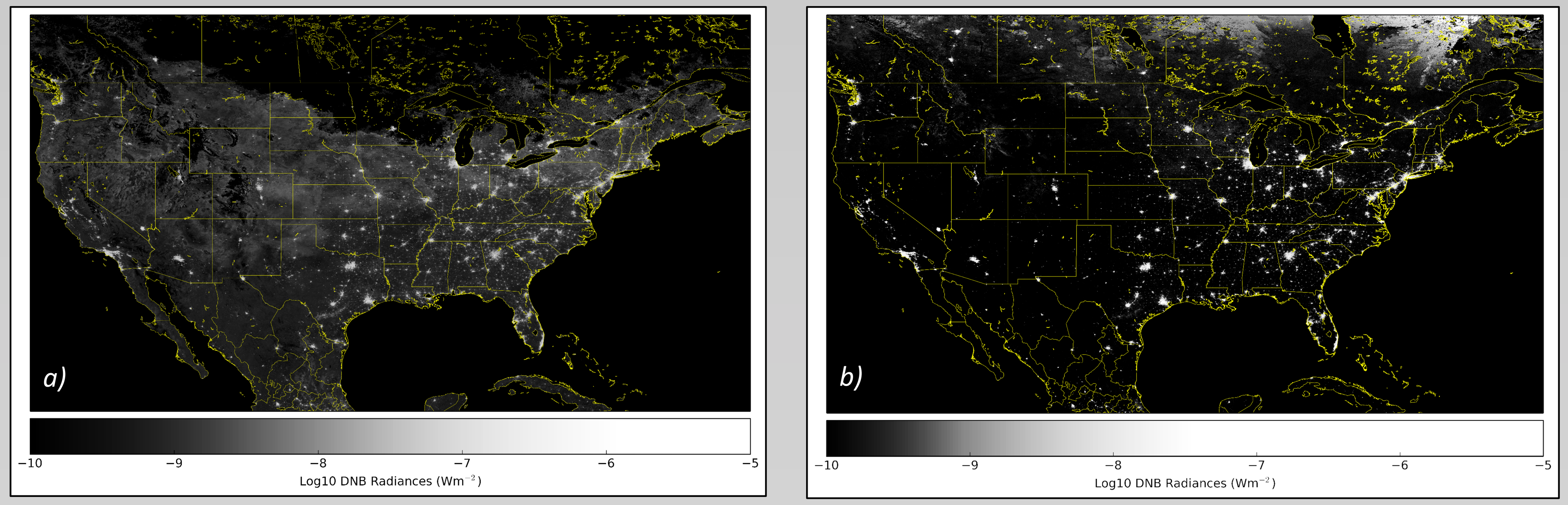

Figure 3 (a-b): (a) Mean pixel value over CONUS during 2013 and (b) Minimum pixel value over CONUS during 2013. Data was pre-processed to remove clouds and filter only high-quality, snow-free observations.

Variability in the Southeastern United States

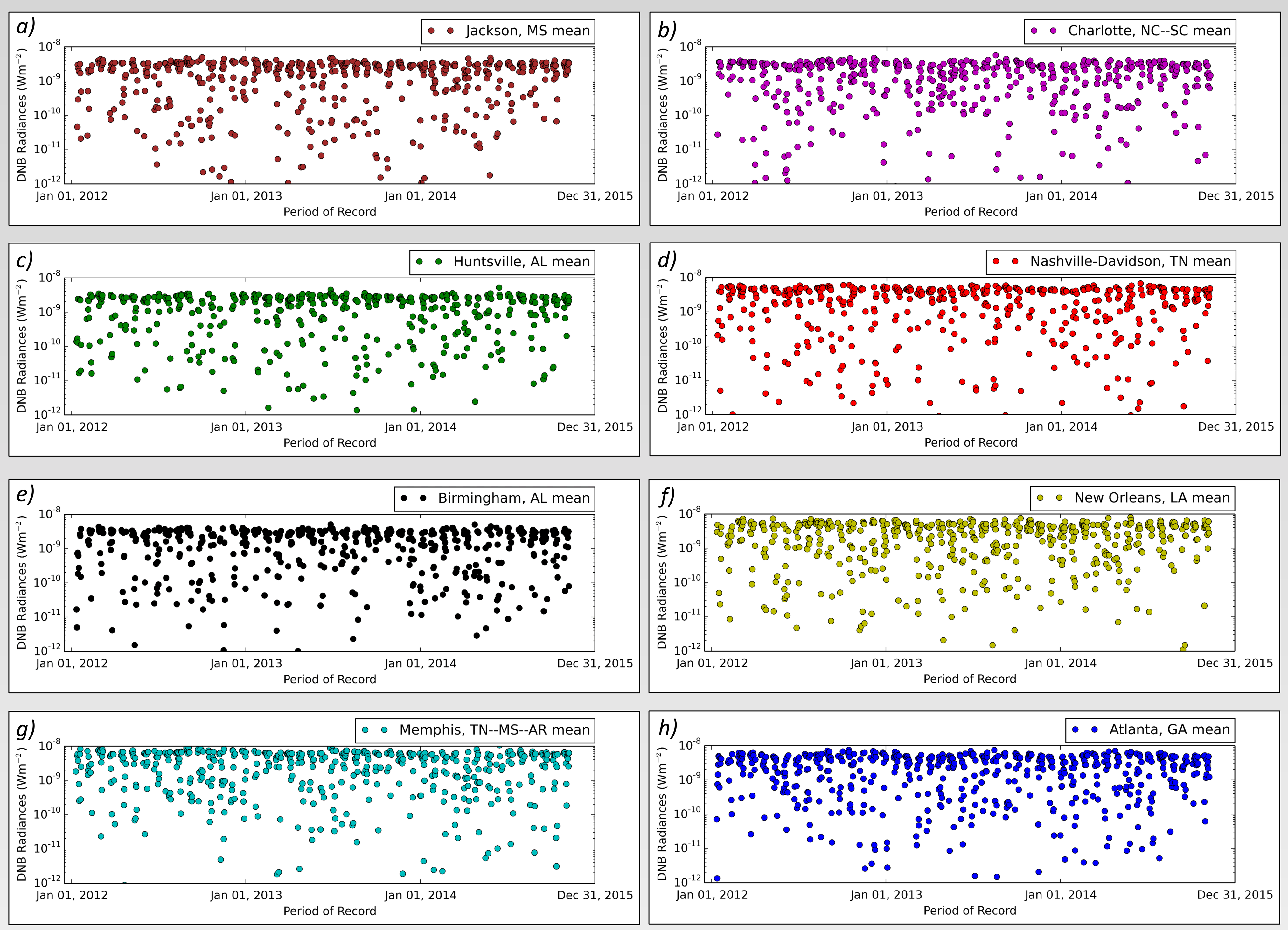

Figure 4 (a – h): Temporal light variability for eight cities in the southeastern U.S. The majority of emissions fell between $1x10^{-8}$ and $1x10^{-9}$ Wm^{-2} for the entire period of data record (1/19/12-9/10/15), however many observations fell below the overall mean. These reduced emissions are topics of further analysis to determine their cause.

Frequency of High Quality Data Observations

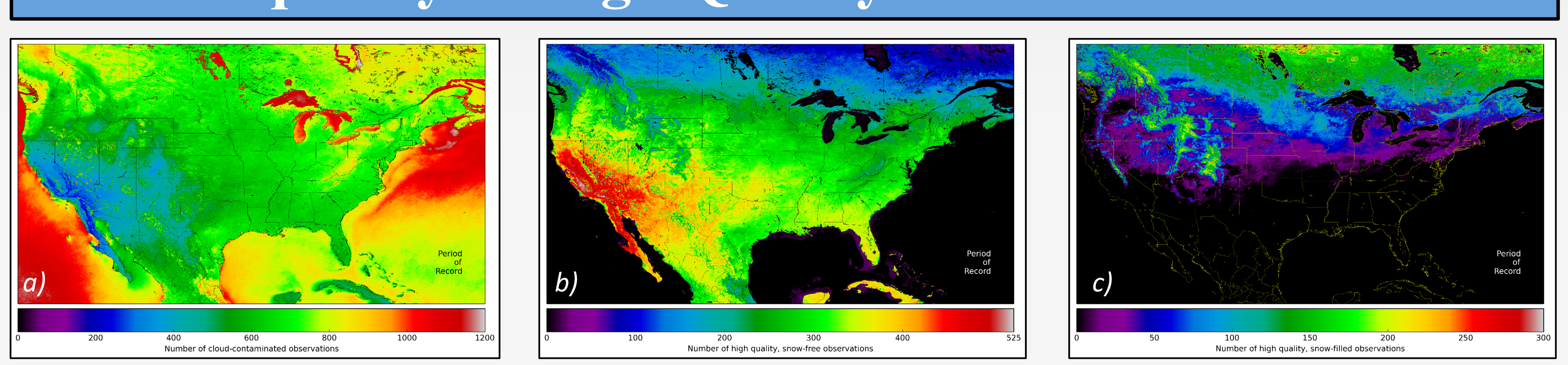

Figure 5 (a – c): Quality flags plotted over the entire period of data record (1,325 nights) for (a) cloud-contaminated pixels, (b) high-quality snow-free observations and (c) high-quality snow-fill observations. Understanding the relative occurrence of the high quality data is beneficial for estimating the number of observations that can be used for power outage detection.

Example Power Outage Case Study

- Hurricane Isaac made landfall in Louisiana on August 29th, 2012
- Along with strong winds and damaging rains, power was disrupted for an estimated 890,000 customers
- By compositing 30 pre-event images, a baseline is computed as "normal" lights
- Single, post-event images can detect damage and monitor recovery
- A pixel-based percent of normal is computed by:

$$Percent_{normal} = 100*(Post/Pre),$$

where post is a single cloud-free, post-event image and pre is a 30-day running mean composite

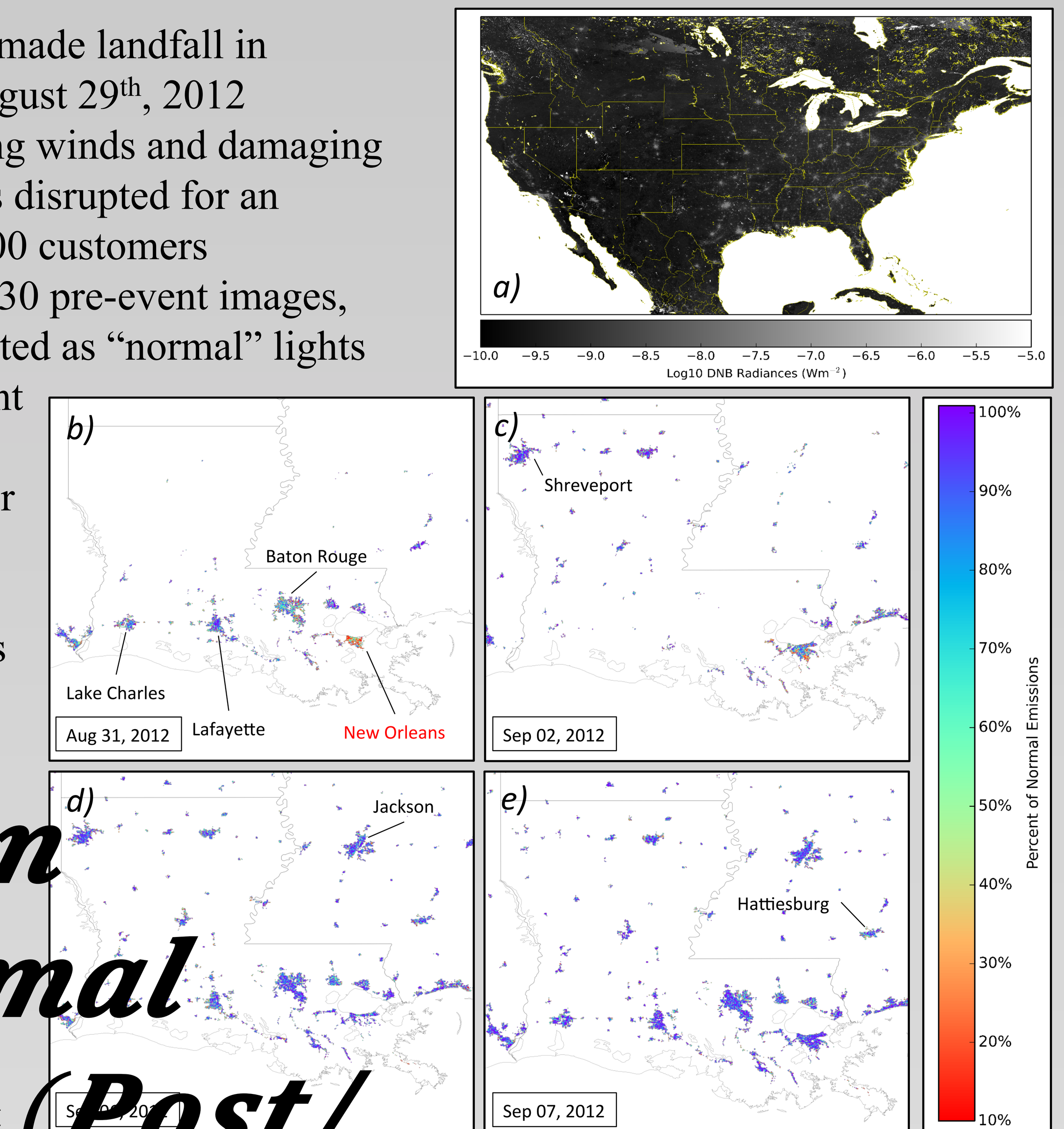

Figure 6 (a-e): (a) Pre-event 30 image composite over CONUS, (b) earliest cloud-free, post-event single image showing most of New Orleans less than 40% of normal with some estimated damage along Baton Rouge, (c) secondary post-event image shows initial recovery for parts of New Orleans; Baton Rouge is under cloud cover and (d,e) near-full recovery a week post-event.

Conclusions

- City lights provide insights to human activity at night
- Understanding how city lights fluctuate over time is vital to understanding the statistical significance of any reductions due to severe weather
- Observations from the VIIRS DNB have potential for use to monitor these features
- Preliminary variability trends over nearly four years are shown for eight cities in the southeastern U.S.
- A method is also proposed to detect reductions in these lights by comparing cloud-free, post-event single images to a 30-day, pre-event image composite

Future Work

- Alternative approaches for analyzing city light variability such as standard deviation of observations will be explored
- Quantifying reductions after severe weather events through departures from a pre-event sigma could improve detection
- A spatial data set of documented power outages following a severe weather event would provide an opportunity for validating estimates like those shown above

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